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The X-ray nature of the LINER nuclear sources

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Abstract. The analysis of the X-ray data for a sample of 51 LINER nuclei with available X-ray Chandra imaging is reported. Our aim was to investigate the physical mechanisms which power LINER nuclear activity. The use of multiwavelenght information at radio, UV, optical HST and X-ray lead us to conclude that at least 60% of the LINERs are hosting a low luminosity AGN in their nuclei. This percentage may be even higher if the Compton-thickness of some nuclei (mostly with SB-like hard X-ray morphology) is confirmed.

1. Introduction

Pioneering works already estimated that at least 1/3 of all the spiral galaxies are LINERs (Heckman et al. 1980). If they represented the faint end of the AGN luminosity distribution, their study would be crucial for the understanding of AGN activity, in particular in our nearby universe. But still nowadays, there is an ongoing strong debate on the origin of the energy source in LINERs, with two main alternatives for the ionizing source: either it is a low luminosity AGN, or it has a thermal origin related to massive star formation and/or from shock heating mechanisms resulting from the massive stars evolution. The search for a compact X-ray nucleus in LINERs is indeed one of the most convincing evidence about their AGN nature.

2. The sample and the data

The catalogue by Carrillo et al. (1999) provides 476 LINERs with information from radio to X-rays. Our sample comprises all the LINERs in this catalogue with enough quality data (at least 25 counts in the range 0.5-10 keV) in Chandra-ACIS archives, made public up to Novembre 2004. This sample amounts to 51 LINERs, which resulted to be representative of the bright optical LINERs (see González-Martín et al. 2006, for details).

3. X-ray Analysis

Attending to their hard X-ray (4.5-8.0*keV band) morphology the sample has been grouped into two categories: (a) **AGN-like Nuclei**, with unresolved nuclear point-like source, and (b) **Starburst-like Nuclei**, with no detection of a nuclear point-like source.

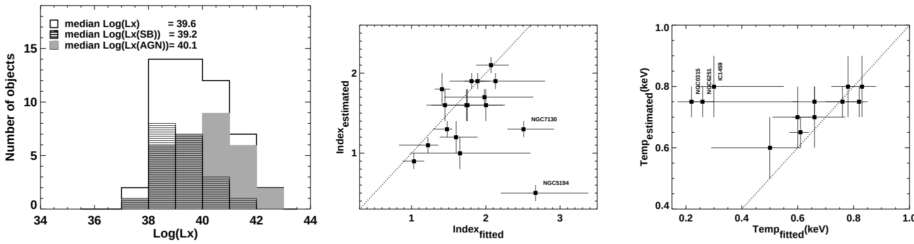

Figure 1. (Left): Luminosity histogram for the whole sample (empty); objects classified as AGN-like (grey) and Starburst-like objects (dashed). Comparison between power-law index (centre) and temperature (right) as estimated from C-C diagrams with those from fitted values.

The spectra from 0.5 to 10 keV have been fitted. Two models (thermal and non-thermal), and their combination, were tested to account for the spectral emission of the 23 objects with enough S/N, including absorption (phabs) and using solar metallicities and χ^2 statistics. Only one object can be better fitted with a pure thermal model, whereas for 7 of them a pure power law is a better description. A combination of thermal and non-thermal components is required in the remaining cases. The resulting median spectral parameters are kT=0.64±0.17 keV and Γ=1.89±0.45.

Nuclear luminosities were calculated from the best-fit model for these 26 galaxies, or estimated assuming a power law of $\Gamma = 1.8$ and galactic absorption for the remaining 28 galaxies, for which no spectral fitting is possible. Fig. 1 (left) shows that AGN-like nuclei tend to be more luminous than SB-like nuclei.

Color-color (C-C) diagrams have been defined and optimized to estimate Γ, kT, and n_H when the spectral fitting is not possible. Fig 1 shows the comparison between estimated and fitted values. Excepting three cases, the C-C diagrams provide a good T estimation, and Γ results to be slightly underestimated.

4. HST imaging

Sharp-divided images of the objects with available HST imaging (43 galaxies) are used to classify our sample LINERs into two groups: (a) compact nuclear sources (35 objects); and (b) dusty nuclear regions (8). All the galaxies classified as AGN by the X-ray imaging analysis show compact nuclei at the resolution of HST images.

5. Results

From the X-ray analysis, about 60% of the LINERs in our sample are AGN candidates. These objects are, on average, more luminous in X-rays (2-10 keV), but their luminosities share a large overlapping range with SB candidates. Both the luminosities and the morphological classes generally agree with those in previous studies (Ho et al. 2001, Satyapal et al. 2004, 2005, Flohic et al. 2006). The temperatures for the soft thermal component (kT≈ 0.6-0.8 keV) are similar to those in starbursts (Ott et al. 2005, Grimes et al. 2005), and higher than

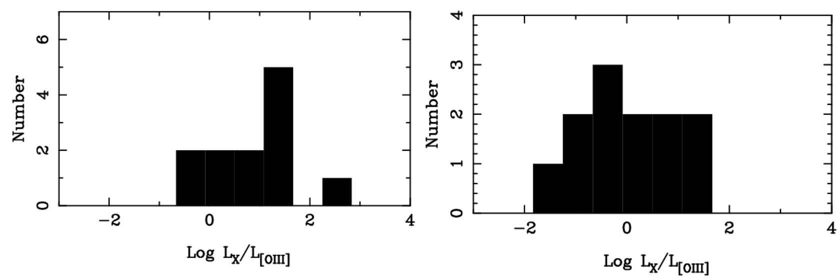

Figure 2. $L_X/L[OIII]$ ratios for AGN (left) and SB (right) candidates in our LINER sample. Compton-thick sources should have $\log(L_X/L[OIII]) < 0$.

those found for Seyfert 1 nuclei (kT$\approx$ 0.25 keV, Panessa et al. 2006). The hard power-law slope for LINERs ($< \Gamma >$=1.8) is within the range found for Seyferts (Cappi et al. 2006 have found $< \Gamma >$=1.56 and 1.61 for Sy1 and Sy2, respectively).

To gain insight into the emission mechanisms in these objects, we looked for other evidence of the AGN nature at other wavelenghts:

HST Analysis: All AGN candidates show compact HST nuclei (28 galaxies). SB candidates (15) show both dusty (8) and compact (7) HST nuclei. Among the seven SB candidates with unresolved optical nuclei, 4 show other evidences of hosting AGN both in optical (broad or double-peaked Hα emission line) and radio (see below).

Radio Evidence: An unresolved nuclear radio core and flat continuum have been suggested as an evidence of AGN nature. Most of the LINERs in our sample classified by Filho et al. (2000) as AGNs in radio (13 objects) result in AGN-like class in X-rays (9).

UV variability: For the 7 objects in common with the sample of 17 LINER galaxies with HST/UV data by Maoz et al. (2005), five show time variability hinting to their AGN nature; all of them belong to our AGN-like class.

Stellar populations: For the 14 galaxies with data available (Cid-Fernandes et al. 2004) the contribution of young stars is always less than 3%. Therefore, High Mass X-ray Binaries are not expected to be an important ingredient for the nuclear X-ray emission.

6. Compton Thickness

$L_X/L[OIII]$ may be used to detect Compton-thick sources ($L_X/L[OIII] < 1$, Maiolino et al. 1998). In Fig. 2 this ratio is shown for the 24 LINERs in our sample with available [OIII] luminosities, separately for AGN (left) and SB (right) candidates. It can be seen that SB-like nuclei show lower values than AGN-like (mean values 0.96 and 11.0, respectively). The high percentage of SB-like in the region occupied by Compton-thick objects (50%) imply that they may host a strongly obscured AGN. This issue will be further analysed by searching for the presence of Fe lines in XMM spectra.

7. Conclusions

From the study of the nuclear properties of a sample of galaxies with LINER nuclei we have obtained that:

- From the X-ray morphology, 60% of the LINERs are classified as AGN-candidates.
- Most of the objects need both thermal and non-thermal components for the spectral fitting. C-C diagrams confirm this result.
- All the galaxies classified as AGN by the X-ray imaging show Compact nuclei in the optical at the HST resolution.
- Nine of the objects showing AGN nature at radio frequencies belong to our AGN-like class.
- Seven LINERs are variable at UV; all of them are AGN-like.
- High Mass X-ray Binaries are not expected to be an important contribution to the X-ray emission.
- A high percentage of the nuclei in our SB-like class may host strongly obscured AGNs.

Although contributions from HMXBs and ULXs cannot be ruled out for some galaxies, we concluded in González-Martín et al. (2006) that 60% seems to be a lower limit for LINERs hosting an AGNs. The analysis of the Compton Thickness hints to a high percentage of our SB-like LINER nuclei hosting strongly obscured AGNs.

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